RUMINAL FILL EFFECT OF FORAGES: PREDICTION AND RELATIONSHIP WITH VOLUNTARY INTAKE

R. Baumont, A. Barlet and J. Jamot
Station de Recherches sur la Nutrition des Herbivores, INRA, Centre de Clermont-Fd/Theix, 63122 St-Genès-Champanelle, France

ABSTRACT
Voluntary dry matter intake (VDMI) and rumen fill were measured on sheep fed with 18 forages ranging from wheat straw to lucerne hay. *In vivo* fill effect (IVFE i.e. rumen DM pool divided by VDMI), *in situ* degradability, cell-wall composition, pepsin-cellulase digestibility and in vitro gas production were determined. *In situ* estimated fill effect (ISFE) was calculated as the retention time of insoluble potential degradable and undegradable fractions using a constant rate of passage. ISFE and IVFE were highly correlated (r^2=0.89) but ISFE values were lower than IVFE values because *in situ* degradability does not integrate comminution time of large particles. NDF content, pepsin-cellulase digestibility and gas production were good predictors of IVFE (r^2=0.86, 0.90 and 0.91 respectively) and to a lesser extent of VDMI (r^2=0.78, 0.88 and 0.84).

KEYWORDS
Forages, rumen fill, voluntary intake, prediction, sheep

INTRODUCTION
Forage intake is primarily limited by the physical load of the forestomachs. Prediction of ruminal fill effect of forages should therefore be useful for the prediction of voluntary dry matter intake (VDMI). Ruminal fill induced by a given amount of ingested feed is a function of the residence time of feed in the rumen. This residence time can be assessed by dividing the pool of dry matter (DM) in the rumen by the total flow of DM taken in that is VDMI. It provides an *in vivo* measurement of forage fill effect (IVFE). Ruminal fill effect has been estimated using *in situ* degradability (Madsen et al., 1994). *In situ* estimated fill effect (ISFE) is calculated by the retention time of insoluble potential degradable and undegradable fractions. The aim of this study was to investigate i) the relationships between ISFE, IVFE and VDMI, and ii) the use of chemical composition, *in vitro* gas production technique and pepsin-cellulase digestibility to predict IVFE and VDMI.

MATERIALS AND METHODS
Eighteen forages were studied on sheep between 1986 and 1995 : two wheat straws, three urea-treated straws, five meadow grass hays cut in the first cycle of vegetation, three cocksfoot hays cut in the second cycle of vegetation, two cocksfoot silages and three lucerne hays. Each forage was fed in chopped form to five or six fistulated Texel wethers for measurement of VDMI and of rumen DM pool by manual emptying (Baumont et al., 1990). *In situ* degradability using nylon bag technique (Demarquilly and Chenost, 1969), *in vitro* gas production using rumen fluid (Menke and Steingass, 1988), *in vitro* pepsin-cellulase digestibility (Aufrère and Demarquilly, 1989) and cell-wall composition (Goering and van Soest, 1970) were performed on dry samples. *In situ* degradability data were fitted on the model proposed by Orskov and Mc Donald (1979). IVFE and ISFE were calculated as follows:

$$\text{IVFE (day)} = \frac{\text{mean DM pool in the rumen}}{\text{VDMI}}$$

$$\text{ISFE (day)} = \left(\frac{b}{c+k} + \frac{1-a-b}{k}\right) / 24$$

where a is the rapidly degradable fraction, b is the potential degradable fraction, c is the rate of degradation (h^{-1}) and k is the rate of passage (h^{-1}). For k, a constant value of 0.027 h^{-1} was used, based on the measurement of the rate of passage of lignin on 11 of the 18 forages.

RESULTS AND DISCUSSION
Relationships between ISFE, IVFE and VDMI. The forages used provided a wide range of VDMI from 24.8 to 74.9 g DM/kg $BW^{0.75}$ for wheat straw and lucerne hay respectively. IVFE was negatively related to VDMI (r^2=0.82) and ranged between 0.63 and 1.75 day for lucerne and straw respectively. *In situ* degradability parameters provided a good prediction of fill effect as shown by the high correlation between ISFE and IVFE (Figure 1). However ISFE values were about 80 per cent lower than the IVFE values. As the nylon bag technique was performed on ground forages, ISFE did not integrate the comminution time of large particles in the forage. The correlation between ISFE and VDMI was high but lower than between ISFE and IVFE (Figure 1). This confirms that *in situ* degradability is a good predictor of VDMI (Demarquilly and Chenost, 1969), but that others factors (i.e. palatability, ease of prehension, ...) have to be taken into account.

Laboratory prediction of IVFE and VDMI. For the 18 forages studied, IVFE could be predicted with similar high accuracy by NDF content of the forage, by pepsin-cellulase digestibility or by *in vitro* gas production (Table 1). For gas production the highest correlation was found after 8 hours of incubation in rumen fluid. NDF content, pepsin-cellulase digestibility and gas production after 8 hours were also the best predictors of VDMI, but the prediction of VDMI was less accurate than that of IVFE (Table 1). For prediction of VDMI the highest accuracy was obtained with pepsin-cellulase digestibility. In conclusion, forage fill effect expressed as the residence time of DM in the rumen is negatively and closely related to VDMI. IVFE can be predicted with high accuracy by *in situ* degradability or laboratory methods. The addition of a physical parameter (resistance to grinding, particle size distribution,...) should be necessary to take into account differences in comminution time between feeds or between different physical presentations of the same feed. VDMI prediction should associate prediction of IVFE and other factors such as palatability and ease of prehension.

REFERENCES
Aufrère, J. and **C. Demarquilly.** 1989. Predicting organic matter digestibility of forage by two pepsin-cellulase methods. Proc. 16th. Int. Grass. Cong., Nice, France pp 877-878.

Baumont, R., N. Seguier, and **J.P. Dulphy.** 1990. Rumen fill, forage palatability and alimentary behaviour in sheep. J. Agric. Sci. **115:** 277-284.

Demarquilly, C. and **M. Chenost.** 1969. Etude de la digestion des fourrages dans le rumen par la méthode des sachets de nylon: liaison avec la valeur alimentaire. Ann. Zootech. **18:** 419-436.

Goering, H.K. and **P.J. Van Soest.** 1970. Forage fiber analyses. Pages 1-20 in Agricultural Handbook n½379, Washington D.C., US Department of Agriculture.

Madsen, J., T. Stensig, M.R. Weisbjerg and **T. Hvelplund.** 1994. Estimation of the physical fill of feedstuffs in the rumen by the in sacco degradation characteristics. Livest. Prod. Sci. **39:** 43-47.

Menke, K.H. and **H. Steingass.** 1988. Estimation of the energetic feed value obtained from chemical analysis and in vitro gas production using rumen fluid. Animal Research and Development **28:** 7-55.

Orskov, E.R. and **I. Mc Donald.** 1979. Estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci. **92:** 499-503.

Table 1
Prediction of *in vivo* fill effect (IVFE, day) or voluntary dry matter intake (VDMI; g/kg $BW^{0.75}$) from NDF content (g/kg DM), pepsin-cellulase digestibility (dcel; g/g) or gas production after 8 hours incubation (gas8; ml/g DM)

Y	Equation and factor used			r^2	Syx*
IVFE	-0.810	+	0.00288(NDF)	0.863	0.135
	2.219	-	2.36(dcel)	0.903	0.114
	1.974	-	0.00849(gas8)	0.914	0.107
VDMI	123.4	-	0.109(NDF)	0.784	6.72
	7.216	+	92.5(dcel)	0.884	4.92
	17.87	+	0.323(gas8)	0.844	5.72

* Standard error of prediction

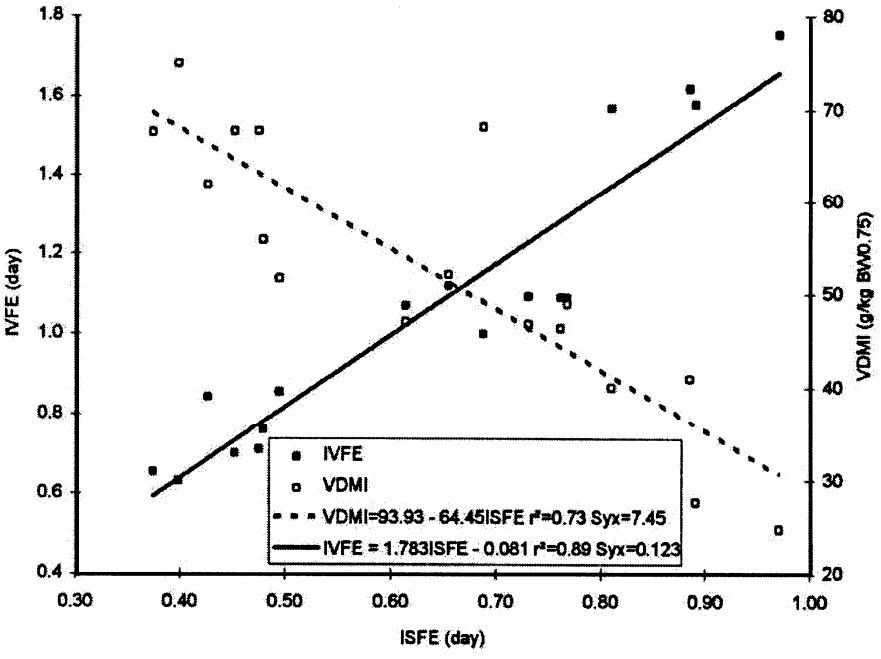

Figure 1
Relationship between *in situ* estimated fill effect (ISFE), *in vivo* fill effect (IVFE) and voluntary dry matter intake (VDMI)